ION Engineering

Bold Science for Clean Energy

Jerrod Hohman, PE

Director of Engineering

NETL CO_2 Capture Technology Meeting
August 22-26, 2011

ION Engineering Boulder, CO

Mission

- Solvent development for efficient low cost separation of CO_2 from industrial gas streams

Markets

- CO_2 capture from flue gas and industrial emissions
- CO_2 removal from natural gas (NG sweetening)

Technology

- Non-aqueous, non-volatile amine solvents
- Background intellectual property secured

DOE/NETL Project Overview

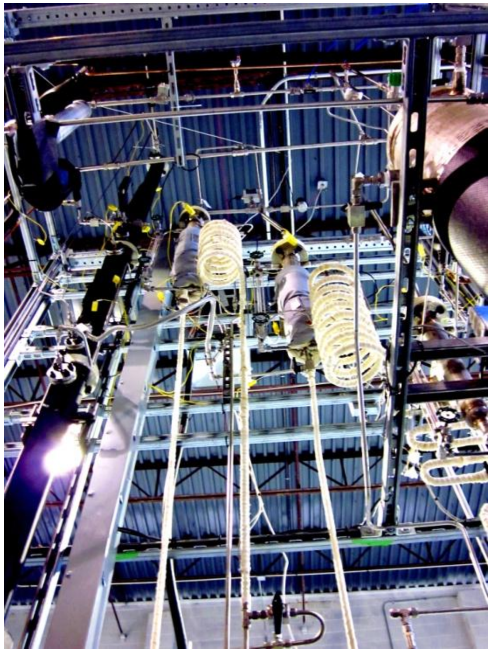
- 20 months (Oct, 2010 – May, 2012)
- Key activities/objectives
  - Solvent testing & validation
  - Laboratory Pilot construction & operation
  - Simulation model development
  - Economic/operational analysis for commercial scale development
- $4M project; $3M funded by DOE

Project participants

Xcel Energy — EPRI Electric Power Research Institute — The University of Alabama — Eltron Research & Development / Continental Technologies — Evonik Industries — WorleyParsons resources & energy

Phase 2 Objectives

- Solvent development
  - Screen prospects
  - Physical characterizations
- Process optimization for specific solvent(s)
  - Process simulation development
  - Lab pilot unit operations
  - Process design studies
- Technical and economic analysis
  - Design basis for reference case power plant
  - Preliminary process design
  - CAPEX and OPEX estimates
  - Impact on COE estimate



Fundamental Science

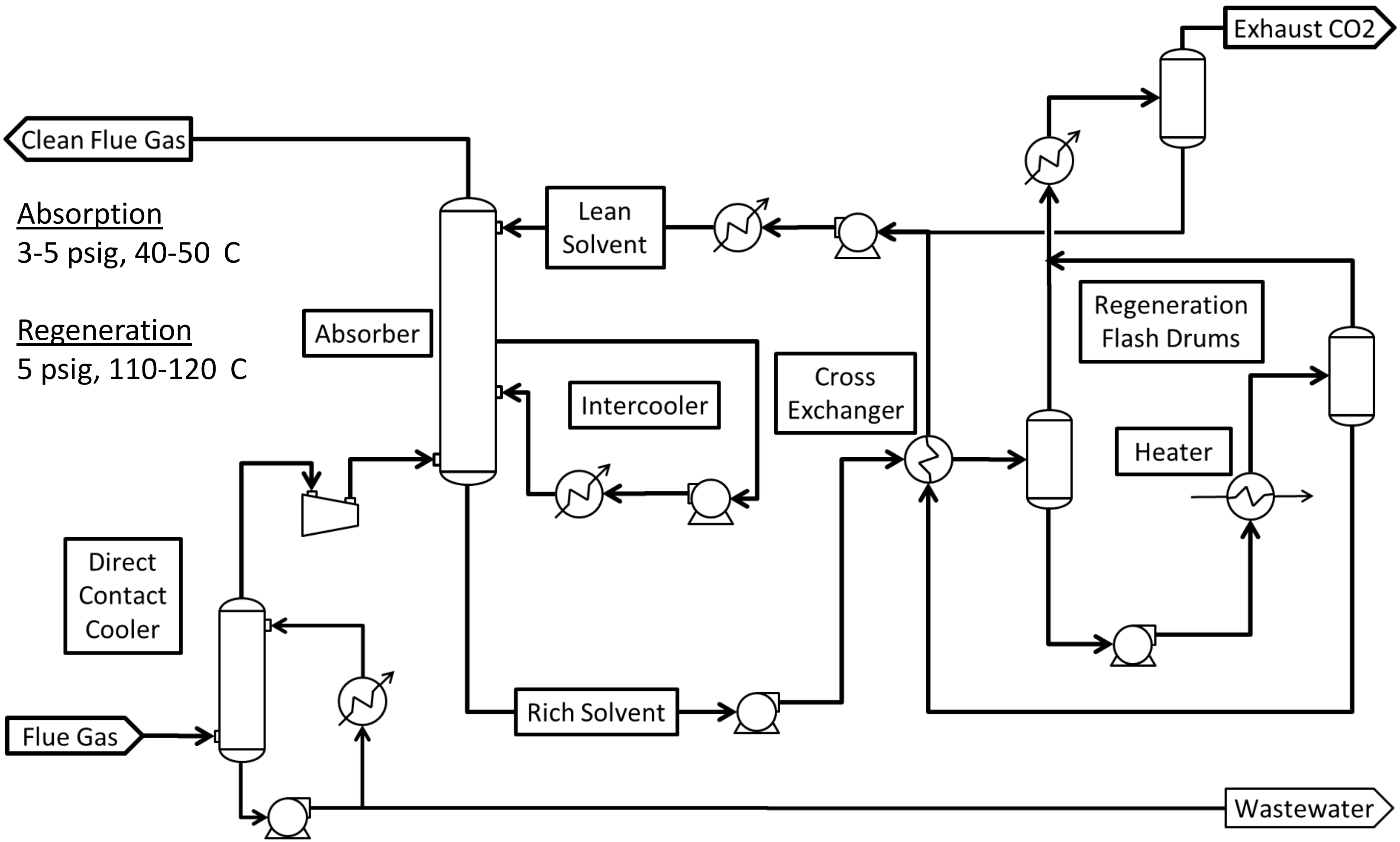
ION's technology replaces the water in traditional amine solutions with a low volatility, non-aqueous solvent

- Advantages
  - Low solvent vaporization = lower regeneration energy
  - Higher solution carrying capacity = lower circulation rates and smaller CAPEX
  - Process flow similar to traditional amines = easy retrofit installation
- Challenges
  - Non-aqueous solvents can have higher liquid viscosity
  - Proprietary solvents are more expensive than water
  - Thermal and chemical instability of amines and non-aqueous solvents

Flow Schematic

Absorption
3-5 psig, 40-50 C

Regeneration
5 psig, 110-120 C



Lab Pilot Unit

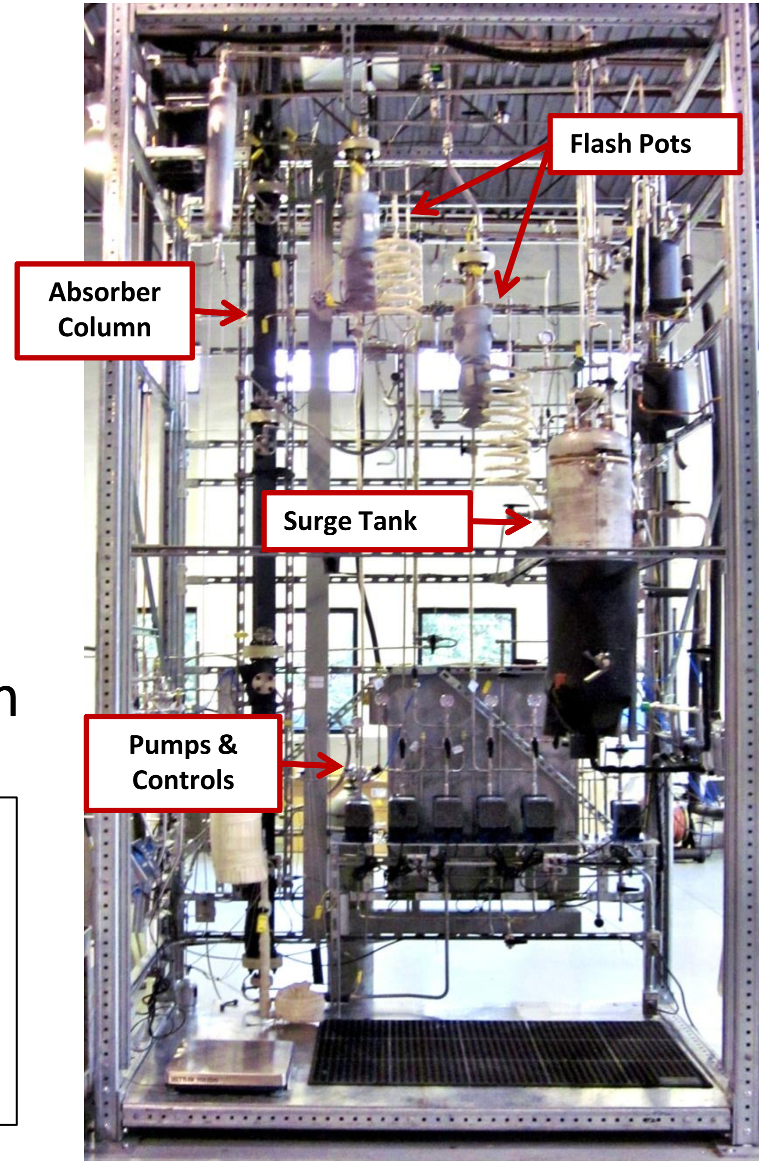
- Packed absorber
- Two-stage flash regeneration
- Online IR CO_2 gas analyzer
- Absorber intercooler
- Closed-loop circulation
- Adjustable inlet gas composition

Circulation Rate: Up to 9 gph

Gas Flow Rate: Up to 200 SLPM

Absorber Pressure: Up to 345 kPa

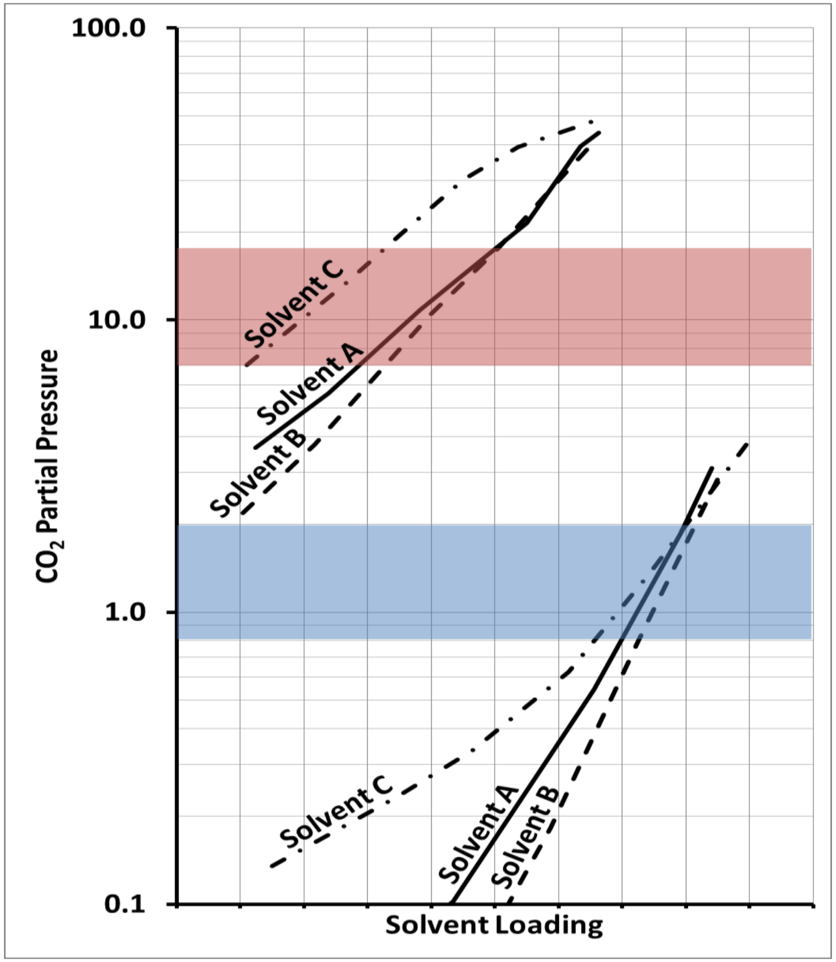
Regeneration Flash Temp: Up to 120 C



Progress and Current Status

- Demonstrated CO_2 absorption and desorption in a continuous process with our first generation solvent
  - Measured the solvent carrying capacity
  - Investigated the impacts of solvent viscosity
- Validated a process simulation with the lab pilot unit
  - Estimated the required solvent regeneration energy
- Identified degradation in first generation solvents
  - Initiated a targeted development program for second generation solvents

Carrying Capacity

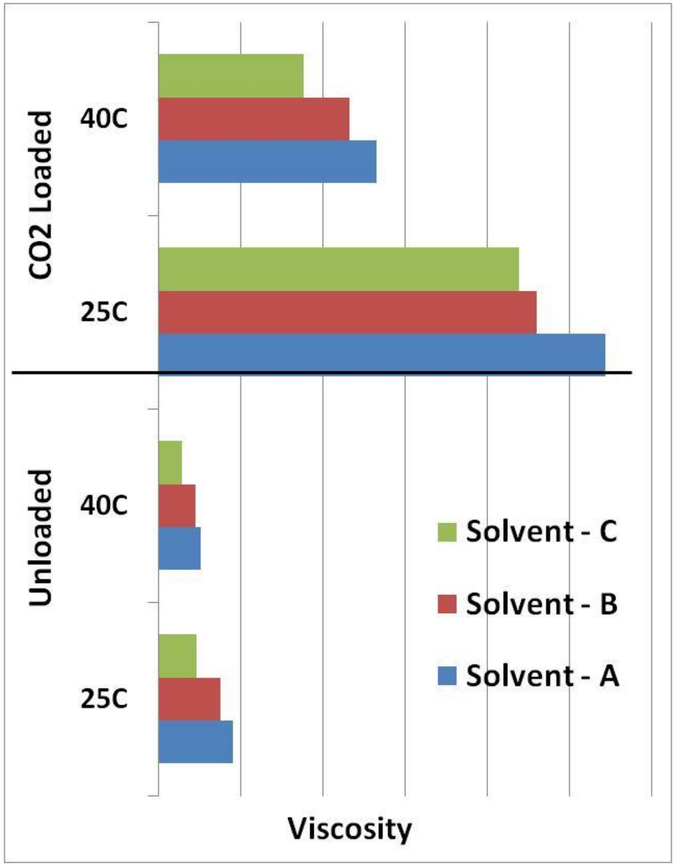


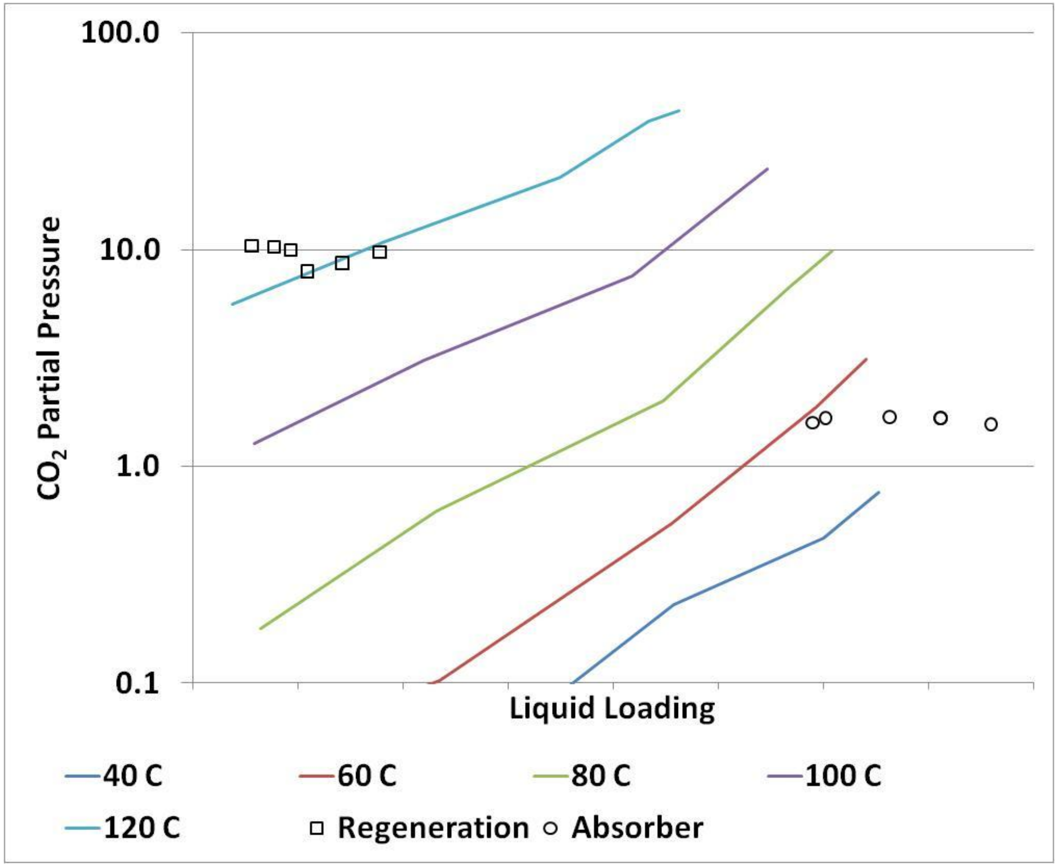
Solvent	Molar Carrying Capacity	Volumetric Carrying Capacity
Aqueous Amine	1.00	1.00
Solvent A	0.92	0.88
Solvent B	0.92	0.93
Solvent C	1.25	1.07

Normalized carrying capacities

- First generation solvents are limited in carrying capacity
- Second generation solvents are showing improvement

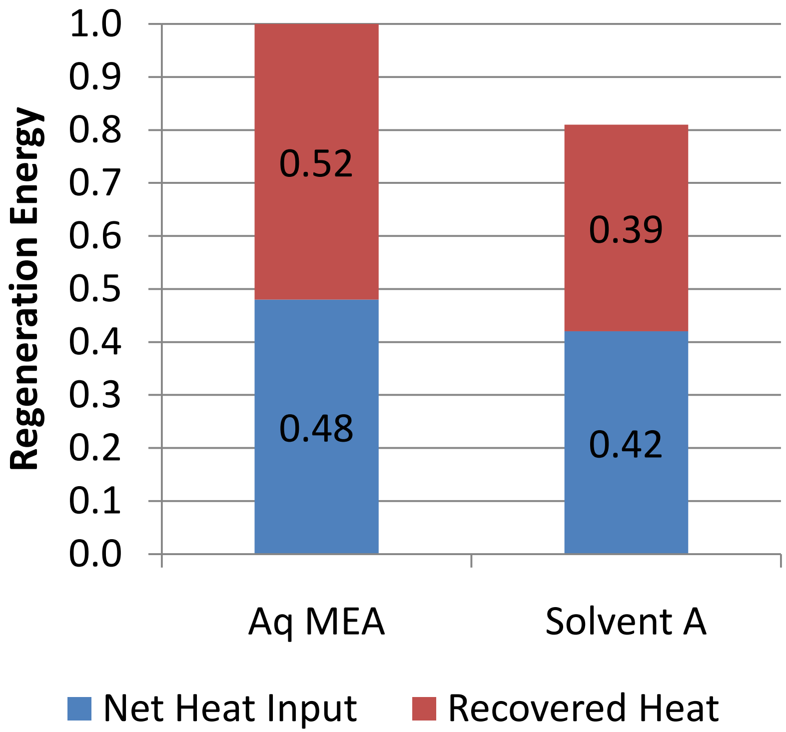
Transport and Viscosity





Even with the highest viscosity solvent we are near equilibrium in the absorber and regeneration systems at operating conditions

Regeneration Energy



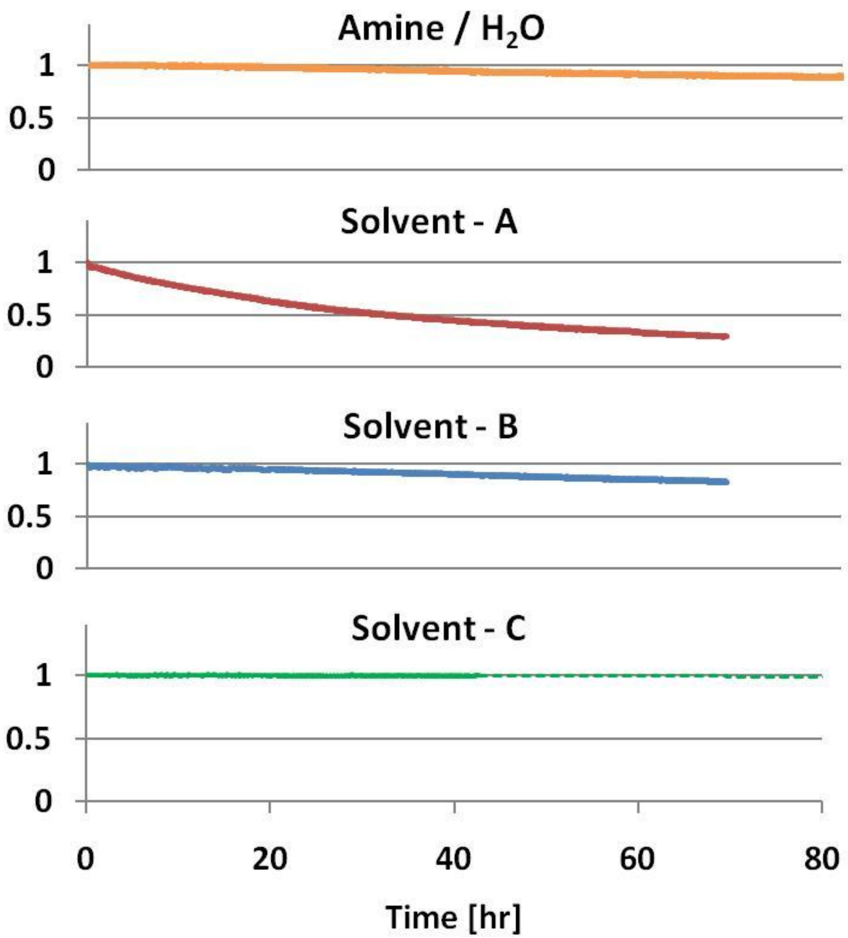
	Aqueous Amine	Solvent A	Effect
Vaporization Energy	1.0	0.4	+
Sensible Heat	1.0	0.7	↔
Heat of Reaction	1.0	1.3	?
Total Energy	1.0	0.8	+

Solvent A shows:

- **19% decrease** in total regeneration energy
- **12.5% decrease** in net heat input

Solvent Development: Stability

Fractional Carrying Capacity



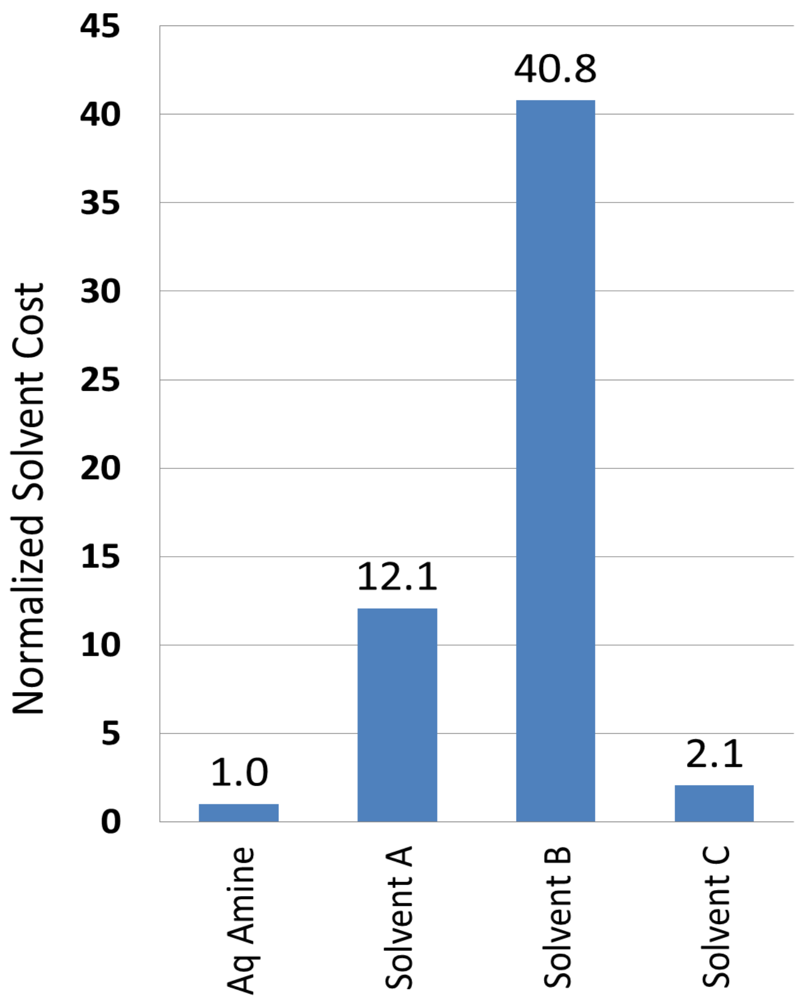
Aqueous amine carrying capacity, for reference

First generation solvent showed significant loss of carrying capacity

Second generation solvents show improved stability

<u>Accelerated (30X) aging</u>
Isothermal 125°C, CO_2 loaded, closed system

Solvent Economics



Solvent A
- Costly solvent with degrading performance

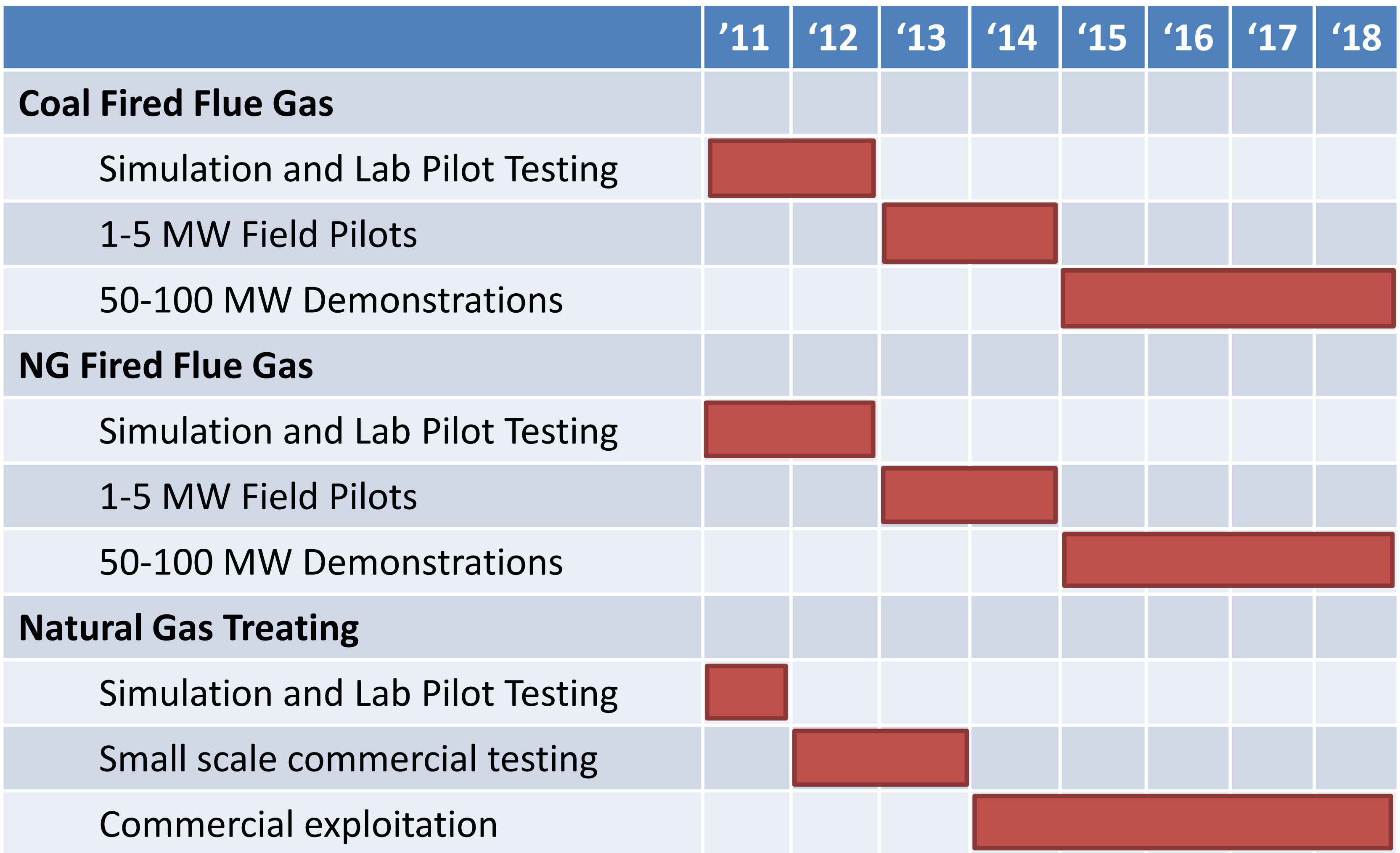
Solvent B
- Expensive solvent with stable performance

Solvent C
- Promising combination of solvent cost and performance

Commercialization Paths & Objectives

- Coal and NGCC Carbon Capture
  - Retrofit aqueous amine units
  - New construction — more efficient, less capital intensive units
  - Commercial Objectives:
    - > 90% CO_2 Capture; < 35% increase in COE
- Natural Gas Treating
  - Retrofit existing aqueous amine units
  - New construction — more efficient, less capital intensive units
  - Commercial Objectives
    - > 10% decrease in annual OPEX; no increase in CAPEX

Commercialization Timeframe



Acknowledgements

NETL

THE UNIVERSITY OF ALABAMA

Xcel Energy® RESPONSIBLE BY NATURE™

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Eltron Research & Development

CONTINENTAL TECHNOLOGIES

EVONIK INDUSTRIES

WorleyParsons resources & energy